

SUMMARY OF LASER SPECKLE PHOTOGRAMMETRY FOR HOST

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High-temperature static-strain measurement capability is important for the success of the HOST program. As part of the NASA Lewis effort to develop the technology for improved hot-section durability, the HOST instrumentation program has, as a major goal, the development of methods for measuring strain at high temperature. Development work includes both improvements in resistance strain-gauge technology and, as an alternative approach, the development of optical techniques for high-temperature strain measurement.

One of the recognized optical techniques for measuring the strain on a surface involves measuring changes in the speckle patterns obtained from photographs of the surface under laser illumination. The photographs, which are taken before and after thermal or mechanical deformation of the surface, capture the surface distortion as a corresponding distortion of the laser speckle pattern. A comparison of the photographs are made on an interferometric photocomparator, which measures differential magnification, which, in turn, corresponds to strain. Under the direction of Dr. Karl A. Stetson, a laser speckle photogrammetry system based on this technique has been developed at United Technologies Research Center. The system consists of a specklegram recording assembly and a interferometric comparator for specklegram readout as shown in figures 1 and 2. This development was partly sponsored by NASA Lewis under contracts NAS3-22126, NAS3-23690, and NAS3-24615. The first of these contracts (NAS3-22126) was a study of methods for measuring static strain on burner liners at temperatures to 870 °C. Under this contract, the laser speckle photogrammetry system was shown to be capable of measuring the thermal expansion of a Hastelloy X sample at temperatures up to 870 °C under laboratory conditions. The test arrangement is shown in figure 3, and some test results are shown in figure 4. Under the second contract (NAS3-23690) the laser speckle photogrammetry system was applied to the measurement of strain on a burner liner operating in a high-pressure, high-temperature, burner test facility at UTRC. A photograph of the combustor liner used in the test is shown in figure 5. The test cell arrangement is shown schematically in figure 6.

One of the problems in the use of this technique is optical distortion caused by turbulent high pressure gas within the viewing path. Although the effects of this distortion can be analyzed if the distortion is precisely known, the turbulence encountered around an operating burner is random and not well documented. One of the objectives of the experimental work in contract NAS3-23690 was to evaluate this problem. The results indicated that, in its present state of development, speckle photogrammetry can only be used at pressures below approximately 3 atmospheres. At higher pressures, turbulence of the gas within the viewing path causes the speckle patterns to blur (see fig. 7) and fail to correlate between photographs.

The objective of the third contract (NAS3-24615) was to demonstrate the use of the UTRC specklegram photogrammetry system on the burner liner cyclic fatigue rig at

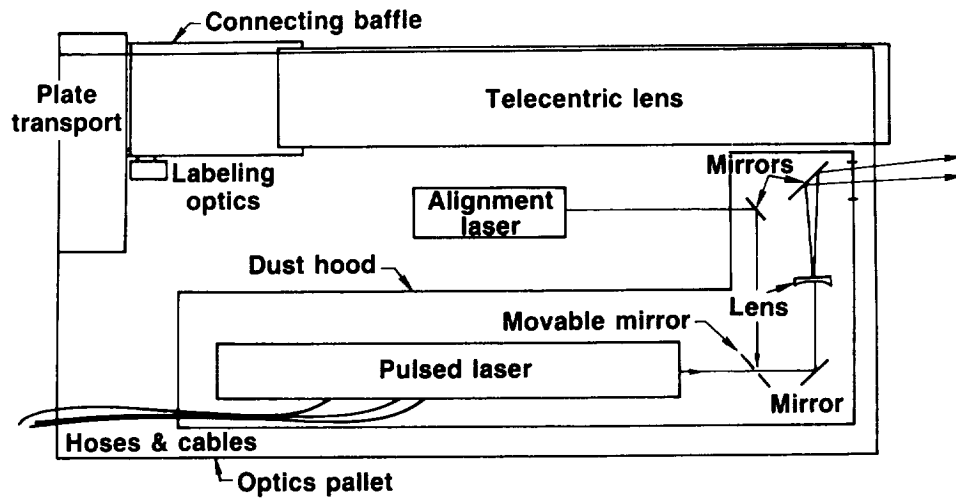
NASA Lewis (fig. 8). In this rig flat plate samples of burner liner material are subjected to cyclic stresses in order to study phenomena such as thermomechanical deformation and fatigue. Because the rig operates at ambient pressure, distortion due to turbulent gas was not expected to be a problem. The contract involved the temporary use of the UTRC specklegram recording system at NASA Lewis to record specklegrams that were subsequently processed for strain data at UTRC using their automated interferometric comparator. Specklegrams were recorded at ambient temperature and at increments of approximately 100 °C up to 900 °C and back down to 120 °C. Following this, three pairs of specklegrams were recorded while cycling between the temperature extreme, and this was followed by a final recording at ambient temperature. Temperature at each data point was monitored by thermocouples and an infrared thermal scanner. The plates from the data run were developed at NASA Lewis. A typical speckle photograph is shown in figure 9. In three data runs 72 specklegrams were recorded and examined. The first set of 24 specklegrams lacked correlation, which was traced to out-of-plane warping and tilting of the sample in the test rig.

Based upon information from UTRC data evaluation of the first run, tests were performed by NASA personnel to check for tilting of the sample. A small spot in the center of the sample was illuminated by a CW laser, and a television camera, focused at infinity, was directed at this spot. The aperture at the center of the telecentric lens was imaged on the camera sensor and appeared on the TV monitor. Speckles were observed within the aperture, and they were seen to move horizontally as the sample was heated. A video recording was made of this speckle pattern for a sequence of heating and cooling of the sample, and this recording was sent to UTRC for evaluation. Between maximum and minimum temperatures, speckles were noted to move about four aperture diameters. This indicated excessive tilting about a vertical axis in the order of 6° due to heating. After mounting the sample more securely, two additional data runs were performed, one at the same temperatures as the first data run and the second with reduced temperature increments. Both of these runs also exhibited correlation problems although to a lesser degree.

The data obtained in these tests show an erratic pattern of strain (see fig. 10). This is particularly true for the data obtained by comparison of the sample before and after a temperature cycle. The important question is whether these data provide a valid description of the strain induced in the sample as a result of the thermal cycling or whether they are the result of turbulence or other artifacts of the specklegram recording system.

In summary at the present state of development, the laser speckle strain measuring system has a demonstrated capability to measure strain at 870 °C in the laboratory. The specklegram recording system has a demonstrated capability of withstanding a test-cell environment and successfully recording specklegrams. The most recently completed tests show that the system is sensitive to extraneous movement of the surface under study. This sensitivity may limit the applicability of the system to experiments in which the surface is precisely located. For applications in more nearly "engine condition" experiments, the limitations imposed by distortion due to turbulent, high-pressure gas within the viewing path, and extraneous movement of the surface under study will have to be overcome. In addition, further work to define the static error boundaries for this measuring system is required. Finally, the development of convenient optical techniques to measure test surface movement, especially out of plane movement and tilting of the surface, is desirable.

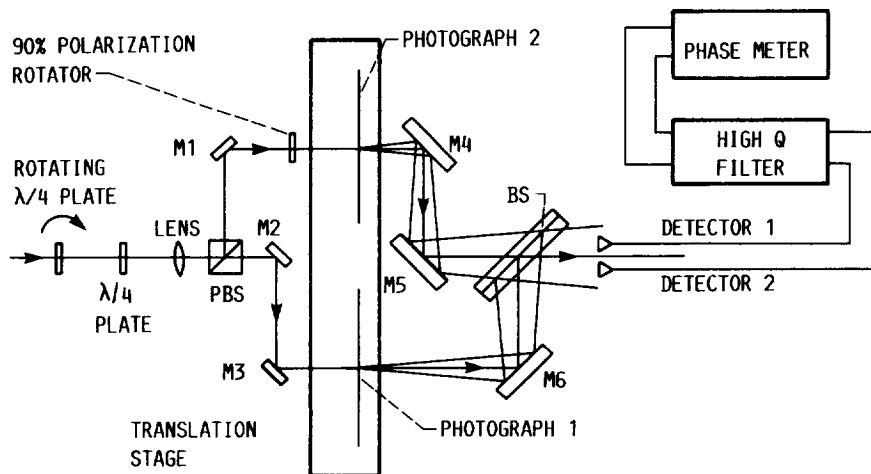
OPTICAL LAYOUT FOR SPECKLEGRAM RECORDING



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Figure 1

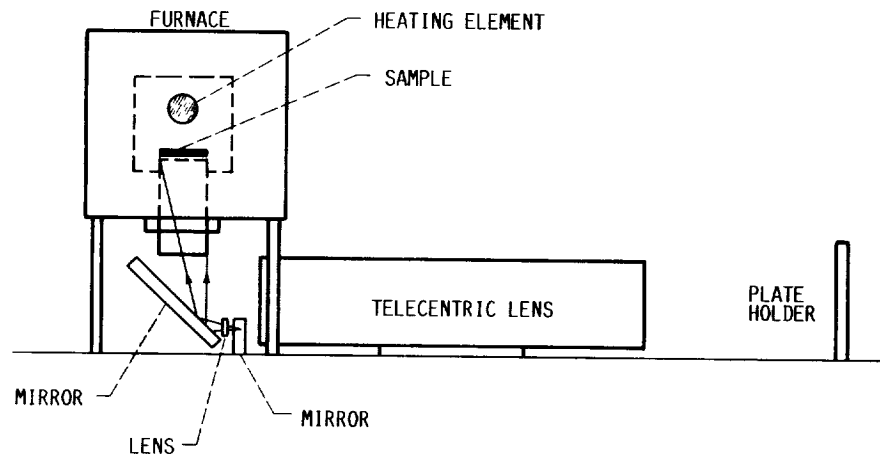
INTERFEROMETRIC COMPARATOR FOR HETERODYNE READOUT OF SPECKLEGRAM HALOS



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Figure 2

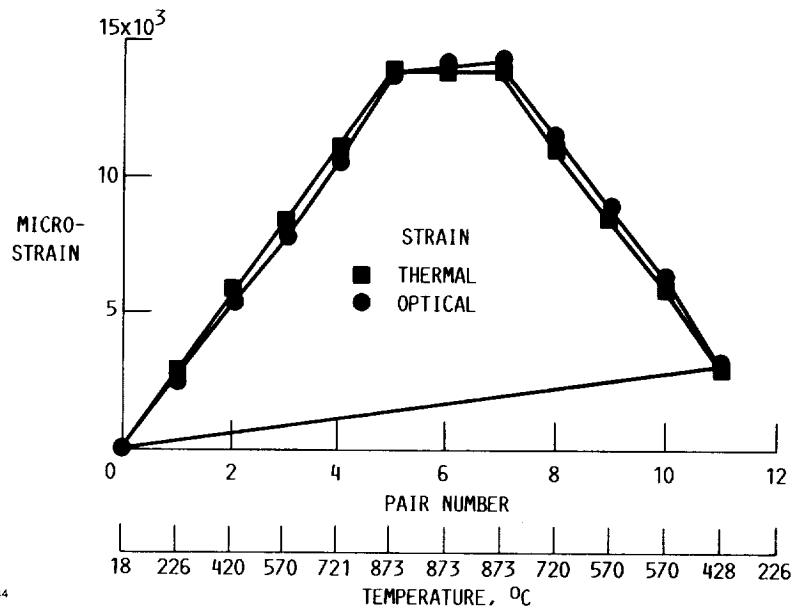
LABORATORY FURNACE AND SPECKLEGRAM RECORDING SYSTEM



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Figure 3

STRAIN HISTORY OF UNCONSTRAINED SAMPLE OF BURNER LINER MATERIAL

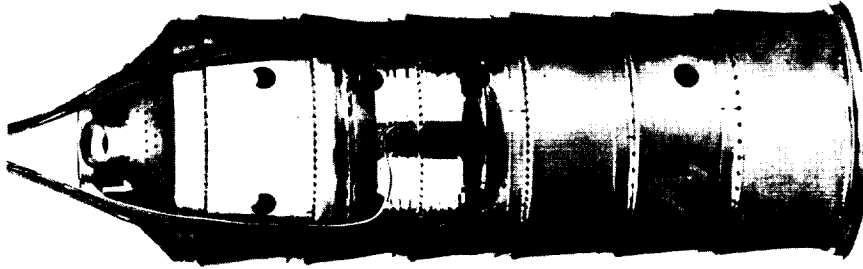


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Figure 4

ORIGINAL PAGE IS
OF POOR QUALITY

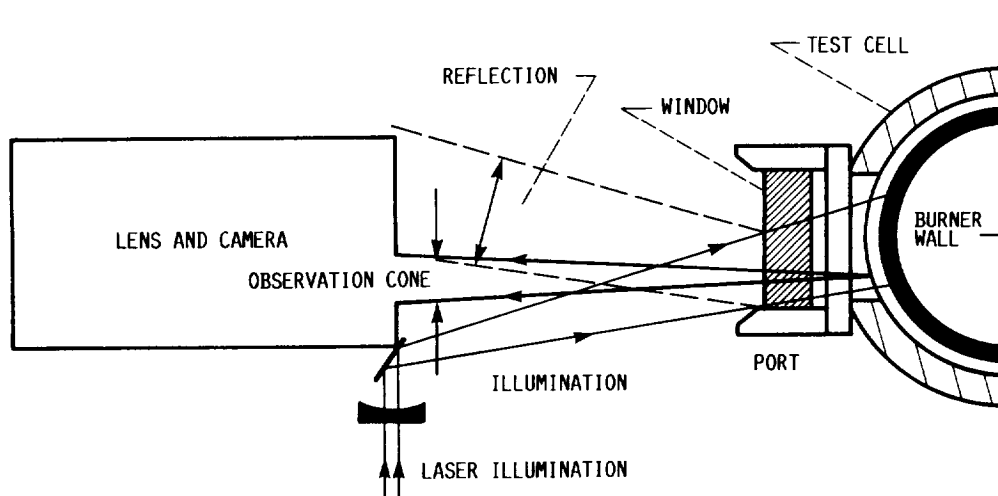
BURNER CAN WITH INSTRUMENTED SECTION REINSTALLED



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Figure 5

TEST CELL ARRANGEMENT



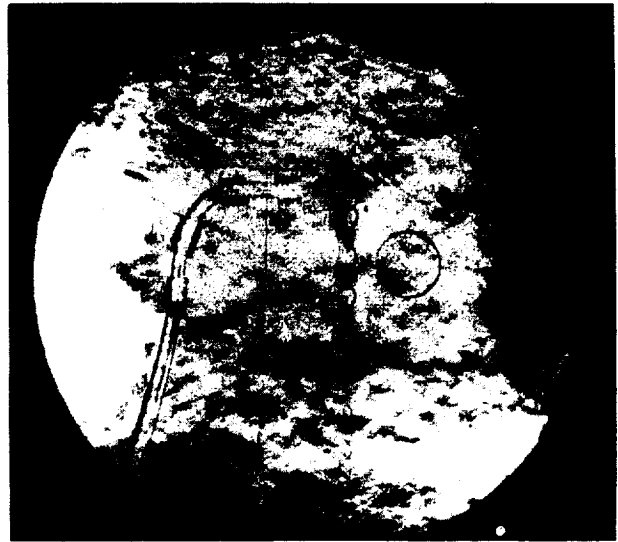
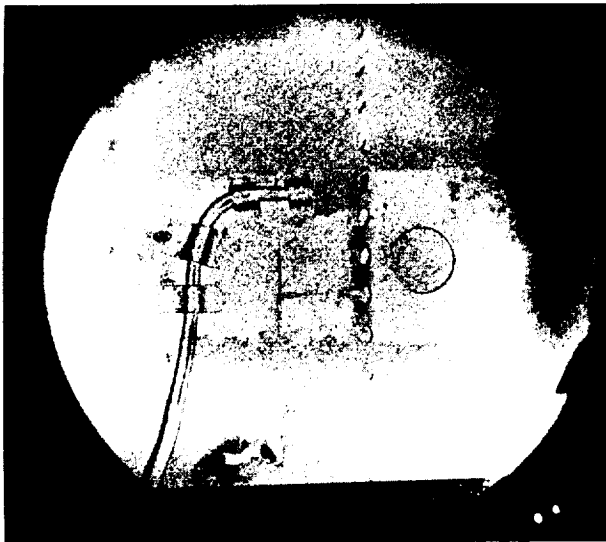
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Figure 6

SPECKLEGRAM IMAGES WITH FOURIER TRANSFORM FILTERING

NO FLOW

FLOW



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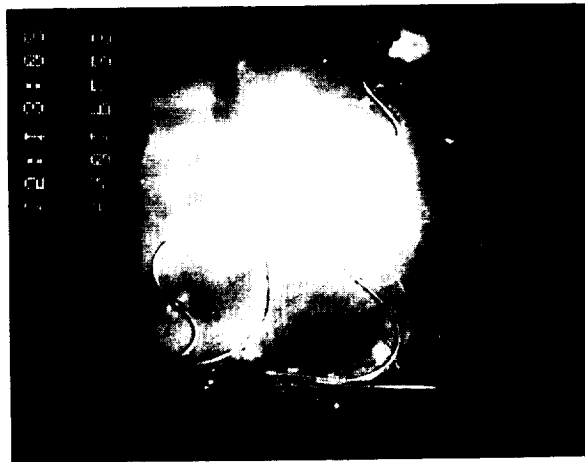
Figure 7



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Figure 8

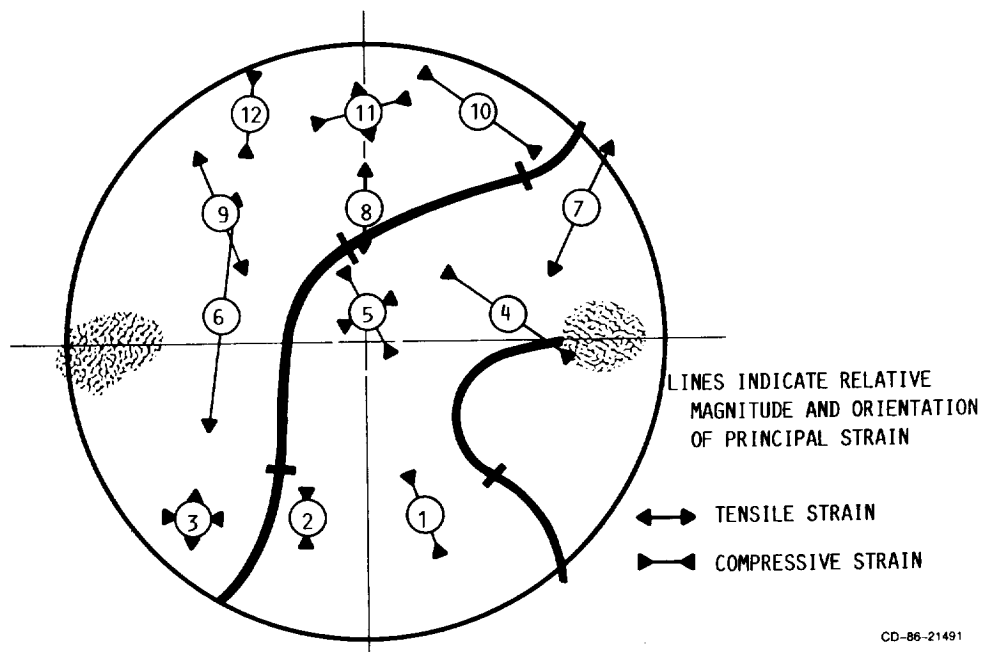
SPECKLE PHOTOGRAPH



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Figure 9

STRAIN DISTRIBUTION AT TWELVE LOCATIONS



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Figure 10

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